DIRECT GROWTH OF BORON NITRIDE NANOTUBES ON SUBSTRATES

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Abstract

We report here the first success of growing boron nitride nanotubes (BNNTs) on substrates. BNNTs have stable electronic properties (band gap of ~5.5 eV), which is independent of the tube diameter, number of walls, and chirality. Furthermore, this band gap can be tuned by substitution of carbon. Thus BNNTs are prospective for applications in nanoscale photonics and electronics devices. Previously, powder form BNNTs have been synthesized at temperatures >1100 °C. These products are mixed of various impurities including catalyst and BN particles. In this report, we describe the growth of BNNTs on substrates at 600 °C by a plasma-enhanced pulsed-laser deposition technique. Furthermore, these BNNTs are vertically-aligned on the substrate surface and can be grown at desired patterns and locations. We have demonstrated the growth of BNNTs in a series of matrix arrays (500 x 500 micrometers). This indicates that their growth is fully controllable by catalyst like the growth of carbon nanotubes. The growth of BNNTs is sensitive to the types of catalysts used, plasma density, and growth temperatures. At optimum condition, a well-defined growth region of BNNTs has been identified and explained. According to high-resolution field-emission scanning electron microscopy (FESEM), these BNNTs are grown in a base growth mode. This has been confirmed by high-resolution transmission electron microscopy (HRTEM). Furthermore, HRTEM indicates that these BNNTs are constructed of well-defined, multiwalled tubular structures with highly parallel tubular channels.

RESULTS AND DISCUSSION

Boron nitride nanotubes (BNNTs) were predicted after the discovery of carbon nanotubes (CNTs) [1]. They are expected to have a wide energy band gap of ~5.5 eV. This band gap is nearly independent of the tube diameter, number of walls, and chirality [2]. This means the electronic properties of BNNTs are uniform. Furthermore, it is possible to tune the band gap of BNNTs by substitution of carbon to make boron-carbon nitride (BCN) nanotubes. It is predicted that BC_2N nanotubes could have a band gap of about ~1.3 eV [3]. Thus BNNTs, and BCN nanotubes could be used for high-power electronic and photonic devices. Promising applications include the nanoscale laser, and light emitting devices (LED) with wavelengths tunable across the visible range into the ultraviolet. BN and BCN nanotubes are expected to accomplish the usage of CNTs as the building blocks for nanoscale devices in the new century.

Both BNNTs, and BCN nanotubes have received far less research attention than CNTs, probably because a high yield synthesis route has not been identified. BNNTs have been synthesized by catalytic arc discharge [4, 5], laser ablation [6, 7], a substitution reaction from CNTs [8], and chemical pyrolysis [9], typically at growth temperatures of 1100 to 3000 °C. Similar difficulty occurred on the growth of BCN nanotubes.

We think that effective growth of BNNTs is important and will lead toward systematic doping of BNNTs by carbon for achieving BCN nanotubes with tunable band gap. Besides a reasonably low growth temperature, accurate positioning of BNNTs and BCN nanotubes on are desired for the fabrication of most nanoscale devices. Here, we describe the first success of growing BNNTs on substrates at 600 °C by a plasma-enhanced pulsed laser deposition technique [10-12].

In Figure 1, images of vertically-aligned BNNTs are shown as detected by a high-resolution FESEM. As shown, these BNNTs can be grown as carbon nanotubes in most chemical vapor deposition technique. We think that this result will lead toward large-scale synthesis of BNNTs by various vapor phase deposition approaches. Details of these results will be discussed in the conference.

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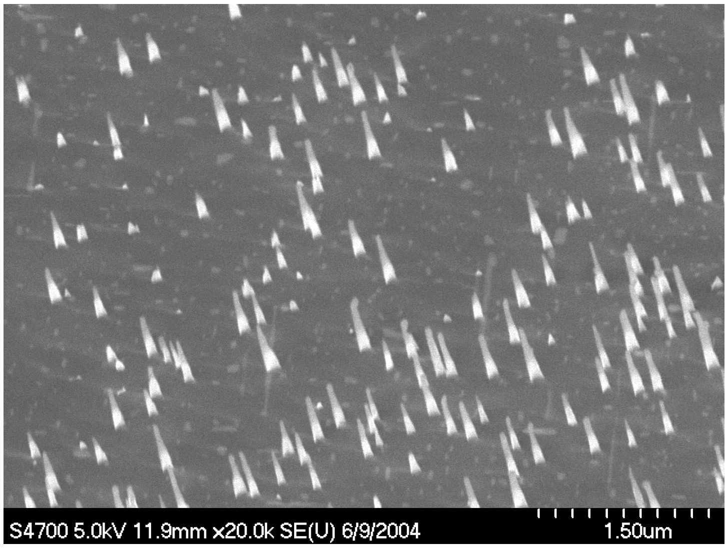

Figure 1. FESEM images of vertically-aligned BNNTs.

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